# Ferroelastic fluctuations in high-temperature superconductors

Fedor V.Prigara

*Institute of Physics and Technology, Russian Academy of Sciences,*

*21 Universitetskaya, Yaroslavl 150007, Russia**

(Dated: September 30, 2009)

## Abstract

It is shown that the specific heat jump at the superconducting transition temperature in pnictide and cuprate superconductors is produced by ferroelastic fluctuations just below the transition temperature. The amplitude of the corresponding lattice distortion is estimated. It is shown that a contribution from ferroelastic fluctuations to the specific heat jump is also present in low-temperature superconductors.

PACS numbers: 74.20.-z, 74.25.Bt, 74.40.+k

Recently, it was shown [1] that the specific heat jump $\Delta C_P$ at the superconducting transition temperature $T_c$ in pnictide superconductors of $Ba\left(Fe_{1-x}Ni_x\right)_2 As_2$ and $Ba\left(Fe_{1-x}Co_x\right)_2 As_2$ series is proportional to $T_c^3$. Since the Debye temperature $\theta_D$ in these compounds is weakly dependent on chemical composition [2] (it is close to those of arsenic As), this relation means that the specific heat jump $\Delta C_P$ at the superconducting transition temperature $T_c$ is about 1% of the lattice heat capacity $C_P$ at this temperature,

$$\Delta C_P \approx 0.01 C_P = 0.01 \times (12/5)\, \pi^4 N k_B \left(T_c/\theta_D\right)^3, \tag{1}$$

where $N$ is the number of atoms and $k_B$ is the Boltzmann constant.

The specific heat jump at $T_c$ in $La_2CuO_{4.093}$ [3] also obeys the relation (1). This relation is produced by ferroelastic fluctuations in the superconducting phase just below the transition temperature [4] and can be attributed to a relative change in the Debye temperature $\theta_D$ at a level of 0.3%. The amplitude of the corresponding lattice distortion $\delta = \Delta a/a$ ($a$ is the lattice parameter) is about $\delta \cong 1.5 \times 10^{-3}$, if we assume that a relative change in the sound velocity has the same order as a relative change in the lattice parameter. This value of $\delta$ has an order of

$$\delta \cong a_0/d_c, \tag{2}$$

where $a_0 \approx 0.45nm$ has an order of the lattice parameter and $d_c \approx 180nm$ is the size of a crystalline domain [5].

The maximum elastic strain in a crystalline solid and, hence, the ratio of the tensile strength $\sigma_s$ to the Young modulus $E$ (for example, in Al, Cu, Fe, Ag) have the same order of magnitude, $\sigma_s/E \cong a_0/d_c$.

A contribution from ferroelastic fluctuations to the specific heat jump at the superconducting transition temperature is also present in low-temperature superconductors. In lead (Pb), the specific heat jump $\Delta C_P$ [6] at the superconducting transition temperature $T_c$ is a sum of the Rutgers term and the term given by the equation (1),

$$\Delta C_P = V\left(T_c/4\pi\right)\left(dH_c/dT\right)^2_{T_c} + 0.01 C_P. \tag{3}$$

Here $H_c$ is the critical field (for type I superconductors) and $V$ is the volume.

The equation (3) is valid for diamagnetic metals (Pb, Sn, In, Tl). In paramagnetic metals (Al, Ta), the specific heat jump $\Delta C_P$ at the superconducting transition temperature $T_c$ is less than the value given by the Rutgers formula, due to antiferromagnetic fluctuations in the superconducting phase [5].

---

[1] S.L.Bud'ko, N.Ni, and P.C.Canfield, Phys. Rev. B **79**, 220516 (R) (2009).

[2] J.K.Dong, L.Ding, H.Wang, X.F.Wang, T.Wu, X.H.Chen, and S.Y.Li, New J.Phys. **10**, 123031 (2008).

[3] T.Hirayama, M.Nakagawa, and Y.Oda, Solid State Commun. **113**, 121 (1999).

[4] F.V.Prigara, arXiv:0811.1131 (2008).

[5] F.V.Prigara, arXiv:0708.1230 (2007).

[6] G.S.Zhdanov, *Solid State Physics* (Moscow University Press, Moscow, 1961) [G.S.Zhdanov, *Crystal Physics* (Oliver and Boyd, Edinburgh, 1965)].

---

* Electronic address: fprigara@recnti.uniyar.ac.ru